

HIGHER EDUCATION, SCIENCE, RESEARCH AND INNOVATION DEVELOPMENT: FROM PANDEMIC RECOVERY TO SUSTAINABILITY

The world today is struggling with the COVID-19 pandemic and challenges in multiple fronts ranging from climate change and environmental degradation to social disparity and technological disruption. These challenges make a big impact to both the economy and society. Technology and innovation can offer solutions to mitigate the impacts of or adapt to these challenges. At the same time, higher education has a unique role in the society as it increases people's skill levels and fosters innovation. Thus, both higher education and science are essential to the sustainable development and resilient society.

The Ministry of Higher Education, Science, Research and Innovation (MHESI) is mainly responsible for Thailand's development of higher education, science, research and innovation. MHESI oversees 286 higher education institutes and 16 research and STI-related organizations, as well as working across ministries to support research and innovation to other ministries' functions. Over the past year, MHESI delivered a number of high impact initiatives to drive the national agenda in various dimensions.

1. Driving a grassroots economy with target poverty eradication approach and area-based development projects such as a community development project by Rajabhat University.
2. Promoting an innovation-driven economy by strengthening manufacturing and service sectors with research, innovation and manpower development. The project to increase the biodiesel blending to B10 represents an example.
3. Enriching the society and the environment by advocating for social wellbeing and cohesion and conserving the environment and ecosystem with projects such as the development and application of hydroinformatics for water resource management.
4. Providing solutions to critical and urgent problems. During the pandemic, MHESI and its organizations have ramped up their effort in developing COVID-19 vaccines and medical supplies and equipment, setting up field hospitals, and creating jobs for people whose employment was affected by the pandemic.
5. Reinventing higher education to meet the requirements for sustainable economy and society with projects such as increasing the number of professional nurses.
6. Reforming higher education, science, research and innovation system to create a dynamic innovation ecosystem with projects such as the development of National Research and Innovation Information System (NRIIS).

Indeed, higher education, science, research and innovation are critical to the sustainability and the vision of Thailand's 20-year National Strategy which is for Thailand to escape from the middle-income trap and become a developed nation. Their latest development and the future outlook are presented in this publication.

SCIENCE, RESEARCH AND INNOVATION DEVELOPMENT

Investment in Science, Research and Innovation

At present, R&D investment in Thailand stands at THB 193.072 billion or 1.14% of GDP, a 5.9% growth from the previous year. Of this amount, 43.828 billion THB (23%) is contributed by the government, whereas 149.244 billion THB (77%) by the industry with the top three sectors being food, petrochemical and finance & insurance. The total number of R&D personnel in full-time equivalent is 166,788 or 25 per 10,000 people, a 4.6% rise from the previous year.

The COVID-19 pandemic is expected to have a negative impact on the R&D investment, especially in the private sector. Drastic drop in R&D spending is anticipated from 2020 to 2022, shrinking to below 1% of GDP before taking off again in 2023. Without the introduction of new measures to stimulate R&D investment, the investment is forecast to reach 1.46% of GDP in 2027, missing the 2027 target of 2%.

The budget allocated for science, research and innovation by the government was THB 12.55 billion for FY2020. The fund was categorized into 1) strategic fund to be administered by funding agencies and, 2) fundamental fund for basic research and functional-based research.

The size of public funding towards science, research and innovation is much smaller than that of the private sector, therefore, the public fund needs to be directed towards stimulating industry investment by: (1) developing a dynamic innovation ecosystem for innovation-driven enterprises (IDEs), (2) facilitating ease of doing innovation business, and (3) introducing supportive measures such as tax incentives.

Capability in Science, Research and Innovation

Smart Farming. Agriculture is an important sector, taking up 55% of the total land in Thailand. The sector is faced with multiple challenges including climate change, increasing demand for food due to growing global population, and technological disruption. Smart farming has been identified as a solution to overcome these challenges. Public and private sectors in Thailand actively engage in the development of smart farming technologies. Examples include Kubota Agric Solution (KAS) developed by Siam Kubota Corporation, an agricultural management tool Agri-Map and the use of satellite remote sensing to improve rice production in Chainat, Roi Et, Ubon Ratchathani and Amnat Charoen. Capacity building program has been implemented for oil palm growers in Krabi and Surat Thani to implement precision farming and bring the production to meet the RSPO standards for sustainable oil palm production. In moving forward, more attention should be given to the development of agricultural machines and IT tools for crop and livestock/aquaculture production, as well as key infrastructure. Higher education institutes and enterprises should be more active in facilitating knowledge and technology transfer to farmers.

Food. Food processing is essential to Thai economic system as it creates value to agricultural products, provides significant employment and generates additional income to farmers and local communities. Thai food products are exported to more than 200 countries at the value of THB 900 billion annually. Currently, the development of technology and innovation in Thailand is well responsive to the global trends covering topics such as insect proteins, plant-based food, functional food, ready-to-eat meals and premium fresh products. The competitiveness of this sector can be elevated by putting more focus on areas such as post-harvest technology, new food processing technology, purification, packaging and cold chain logistics.

Medical Devices. Medical devices industry represents a high potential sector in Thailand with a 6.5% annual growth between 2021-2022. In 2020, Thailand exported THB 158 billion worth of medical devices against the import value of THB 78 billion and held the largest medical device market in ASEAN. Active research is being conducted by Thai academic and research organizations in the areas of medical equipment, diagnostic tests and system and software for medical services. Locally developed innovations that have reached the market include dental implants and titanium orthopedic implants. The accumulated capability enabled the development of COVID-19 solutions such as the RT-PCR test for COVID-19. To enhance the competitiveness of this sector, Thailand needs to accelerate the manpower development, especially in biomedical engineering, support R&D in advanced and complex medical equipment and strengthen the quality infrastructure system.

Genomics. The advancement in genomics and genetic research makes a great contribution to health research, providing insights into genetic diseases and leading to the development of disease prediction, diagnosis and personalized medicine. To support genomic medicine research and enhance the competitiveness of Thailand as a medical hub, the Genomics Thailand was launched in 2020 as a 5-year strategic program to study human genome of Thai population. To further strengthen genomics research, Thailand should invest in building a critical mass of personnel and infrastructure in the areas of medical genetics, molecular biology, molecular pathology, bioinformatics and genetic epidemiology.

Vaccines & Biologics. Thailand's biologics market is valued at approximately THB 40 billion, of which THB 25 billion worth of products are imported. Building biologics production capacity in Thailand will not only reduce imports but also strengthen the national health security. Capability in vaccine and biologics production has long been developed through local R&D and technology transfer and collaboration with foreign partners. Key manufactures include the National Biopharmaceutical Facility of King Mongkut's University of Technology Thonburi, Queen Saovabha Memorial Institute, the Thai Red Cross Society, the Government Pharmaceutical Organization, Siam Bioscience Company Limited, BioNet-Asia Company Limited, and GPO-Merieux Biological Products Company Limited, with a combined vaccine and biologics production worth around THB 1.3 billion annually. Products include, for example, a recombinant acellular pertussis vaccine, an anti-CD6 monoclonal antibody (Itolizumab) for treating psoriasis and a pegfilgrastim biosimilar (PEG-GCSF). To enhance the

competitiveness, Thailand must prepare to develop manpower in medical science and technology and strengthen the national quality infrastructure system to support medical innovation. Focus should be placed on advancing the production from laboratory scale to GMP-PIC/S industrial scale and translation research which can now be serviced by CLINIXIR, a newly established Clinical Research Organization (CRO) in Thailand.

Next-Generation Automotive. Autonomous, Connected, Electric, and Shared (ACES) represent the new trends for future mobility. Thailand is embracing these new trends as they can offer better road safety and reduce pollution and CO₂ emissions. The Thai government announced a target to make Thailand an EV production hub by 2035 and to have EVs constitute 50% of locally made vehicles by 2030. To turn this vision into reality, the government will need to set a clear policy and introduce effective measures to enhance the competitiveness of this industry, including strengthening EV supply chains, fostering industrial clusters and developing a vibrant innovation ecosystem. Areas that need to be addressed are: (1) setting ACES visions and goals for the next 5 years, 10 years and 15 years; (2) raising the industrial capability with technology development, manpower development, R&D infrastructure development, and a supportive regulatory framework; (3) developing charging infrastructure; (4) introducing tax and non-tax incentives; and (5) promoting public awareness.

Creative Economy. In 2018, the creative economy contributed THB 1.461 billion to the economy or 8.9% of the GDP. The top five industries are cultural tourism, Thai food, advertisement, fashion and design. In the Global Creativity Index (GCI) 2015 report published by the Martin Prosperity Institute, Thailand was placed in the 82nd position among 139 countries, ranking 38th in technology, 84th in talent and 105th in tolerance. An action plan for creative economy has been formulated for phase 1 implementation from 2020-2022. The plan aims for a 5% increase in creative goods and services and one city recognized as a creative city by the UNESCO. The plan contains strategies and activities in four areas: (1) knowledge management, (2) talent development, (3) enterprise development, and (4) city planning and ecosystem. In addition, the creative economy has been included in the Bio-Circular-Green Economy (BCG) national agenda to add jobs and generate income by employing creativity.

Circular Economy. The circular economy is among the keys to fight the climate change as it eliminates waste, lowers material and resource consumption and reduces greenhouse gas emissions. Apart from reducing pressure on the environment, the circular concept also offers more business opportunities and create green jobs. At present, research and development in Thailand primarily focus on waste management, not yet embracing the full concept of circularity that intend to eliminate waste and pollution, keep materials in use and seek to regenerate natural systems. To enable the circular economy in Thailand, attention should be paid on promoting research and innovation as well as designing a strong policy and a healthy ecosystem. Energy technology and materials technology are keys to unlock the potential of circular economy. More funding should be allocated to support the circular economy transformation in industry with initiatives such as product development utilizing secondary raw materials. A new organization with a direct mandate on driving the

circular economy is proposed to act as a connector to all sectors and players involved in the value chains.

Innovation-Driven Enterprise (IDE). IDEs are vital to innovation-driven economy and considered the new engine of growth. The Thai government has been promoting the IDE development with initiatives to establish Thailand Science Park in 2002 followed by regional science parks, as well as supportive measures such as an innovation fund for SMEs and the Thai Innovation List to facilitate the government procurement program. The latest survey in 2018 showed that there were 2,480 companies engaging in research and innovation and the number of IDEs with more than THB 1 billion in revenue was estimated to be 812. To raise the number of IDEs, a clear policy and strong action plan are needed to upgrade all types of enterprises – large corporates, SMEs and startups – to IDEs and unicorns in order to produce high value goods and services, create high-paying jobs, and increase the competitiveness in the global market. The policy and action plan should aim to build innovation capability, an IDE ecosystem and develop entrepreneurial mindset and innovation culture.

Innovation Ecosystem. A dynamic innovation ecosystem plays a key role in building a strong economy which leads to wealth and sustainability. Therefore, innovation-driven economies place emphasis on designing proper policies, easing legal barriers and introducing incentive measures to enrich an innovation ecosystem in order to effectively drive the economy and society with innovation. Thailand's innovation ecosystem still has some weaknesses. The government has attempted to close these gaps with initiatives such as an innovation fund for IDEs, the government procurement program supporting innovative products and services, tax and non-tax incentive measures, removing legal barriers to innovation development and reforming higher education, science, research and innovation system. Innovation capacity has been also strengthened through the development of scientific infrastructure – national quality infrastructure and science parks - and manpower especially in the area of innovation management.

Artificial Intelligence (AI). The rapid development of artificial intelligence (AI) has benefited multiple industries and sectors as the world is more and more driven by data and technology. AI market is expected to reach THB 114 billion in 2030 and AI adoption will grow to 50%, up from 17% in 2019. The 2020 edition of the Government Artificial Intelligence (AI) Readiness Index published by Oxford Insights placed Thailand at the 60th position among 172 countries, and 7th among 15 Asian countries. The country had strong advantage in data, and performed moderately in education, skill and innovation. However, its policy and governance needed improvement. Progress has been made in AI research and development in Thai academic and research institutes with some innovations having been put to good use in both the public and private sectors. Examples include Inspectra CXR – an AI platform for chest X-ray image interpretation, CiRA CORE – a system integration platform for robotic automation and AI for industry 4.0 applications, and AI for Thai - a platform providing AI services to users in the manufacturing and service industries. In order to be at the forefront of AI development, Thailand needs to build a critical mass of high skilled personnel particularly in the fields

of AI engineering and data science and develop AI education. A consortium of government agencies, research institutes and industry can facilitate the development of core technologies and infrastructure to support AI innovation, whereas innovation sandboxes will enable innovations as well as workforce to be fully developed.

Advanced Materials. Advanced materials with novel properties or high-performance characteristics are increasingly sought after by all industries. They are central components in a wide range of products, including electronic devices, automobiles, polymers, batteries, electric vehicles, robots, medical equipment and others. As a result, their development can make a profound impact to the economy. Successful innovations by Thai scientists include activated carbon from coconut shell, carbon nanotubes from industrial waste, synthesis of conductive graphene ink and absorbable surgical sutures. Innovation in advanced ceramics and magnetic materials can enhance the competitiveness of Thailand's electronic industry as the country is the major producer of HDDs, integrated circuits, capacitors, diode, transistors and multilayer PCB. As advanced materials are drivers of all 12 new S-curve industries of Thailand, their research should be promoted to be among frontier sciences with substantial funding from the government in the next ten years. An acceleration program to expedite the commercialization process and incentive measures to stimulate domestic and foreign investments will help advance this industrial sector and benefit other businesses downstream.

Quantum Technology. Quantum technology holds promise to enhance the computing, processing, coding, transmitting and storing capabilities of large volumes of data. The technology is crucial for the economic development and national security. The work in quantum technology in Thailand concentrates in three areas: quantum computing and simulation, quantum communication, and quantum metrology and sensing. The country has potential to become a leader in quantum technology due to a sizable number of young Thai scientists who received training from world-class universities and government funding programs dedicated to quantum technology and global partnership. Quantum Technology Foundation (Thailand) is a Thai startup company providing consulting services in quantum computing. Manpower development and public awareness are key areas that should be promoted. A report on Quantum Technology Roadmap 2020-2029 published by NXPO in collaboration with the scientific community can serve as a framework for quantum technology development in Thailand.

Earth Space System. Space technology can benefit the earth and humanities in several ways. Satellites – part of space technology - support communication, earth observation, weather forecast and others. The technology becomes increasingly important to the economy with growing commercial applications, such as space tourism, satellite internet service and commercial satellite data. Thailand relies heavily on foreign technology when it comes to space technology. Satellites used in Thailand were built by foreign companies. Once, there was a project set up for Thai engineers to design and build Thaipat microsatellite under the collaboration with the University of Surrey. However, not much has been done since then to promote research and manpower development in space technology. Socio-economic impact of space industry is

estimated to be THB 35 billion. Manpower development, public awareness and infrastructure development are key areas that should be promoted so that Thailand can reap the benefits of this technology in solving problems such as natural disasters and building the space economy.

Social Sciences, Humanities and Arts. Thailand's recent system reform in science and higher education has led to the close examination of research and innovation system of social sciences, humanities and arts (SHA). NXPO in collaboration with experts in various fields has conducted SHA systems research and published a white paper detailing future setting, blueprint and recommendations to create a system that supports SHA studies and enable knowledge to be utilized in public policy design, social innovation and creative economy. Thailand Academy of Social Sciences, Humanities and Arts (TASSHA) was recently established to drive knowledge creation and manpower development in SHA. The academy comprises five institutes: Institute of Suvarnabhumi Studies, Institute of Sufficiency Economy, Institute of Global Studies, National Art Museum and Institute of Local Arts.

HIGHER EDUCATION DEVELOPMENT

Manpower Development amid Disruption

The World Economic Forum (WEF) has predicted that technological disruption will cause the displacement of 85 million jobs by 2025. Nevertheless, we can expect to see 97 million new jobs in advanced disciplines where digital and human worlds are met. The results of NXPO's study revealed 177,554 new job openings for skilled workforce in 12 target industries in the next five years (2020-2024) with jobs such as data scientists, robotics control engineers, aerospace engineers, material engineers, AI specialists, bioprocess engineers and nutritionists dominating the labor market. Critical functional competencies for each job were also identified in the report.

The rise of the internet has paved the way for the gig economy – a new labor market made up of freelance and part-time jobs. The use of online labor platforms is growing at an annual rate of 25%. On top of specific skills required by each individual job, gig workers in general need to possess skills such as ICT literacy, English language, financial literacy, organizational skills, marketing skills and business skills in order to thrive in the gig economy.

To strengthen the grassroots economy, it is necessary to develop capability and skills of farmers, workers and low-income and vulnerable earners. Information technology skills enable access to information and new business opportunities available online, whereas improvement in productivity, efficiency and value creation can be achieved with knowledge in technology and innovation. Skills such as finance & accounting, management and marketing are important for entrepreneurs.

Adaptation of Thai Higher Education Institutes

Distance learning has become the main mode of education during the pandemic. Although digital infrastructure had been established to support distance learning long before the pandemic, new policies and guidelines were put in place to fit with the situations. Some new programs have been introduced by the government to ease the difficulties faced by students and their families such as tuition fee reduction, a relief fund for students and jobs for students.

Non-degree courses offer an opportunity for learners to gain specific skills to support their current and future employment. At present, there are 677 non-degree courses that build skillsets demanded by target industries, including digital industry, agriculture and biotechnology as well as healthcare industry. These non-degree courses are offered on the Massive Open Online Course (MOOC) platform. The MOOC has 286,000 new enrollments and 570,000 registrants. The “Future Skill x New Career Thailand” is a new platform aiming to retrain workers affected by the pandemic. The platform has 5,270 registrants.

Cooperative and Work Integrated Education (CWIE) is an effective way to prepare students to enter the workplace as it combines classroom-based learning with practical work experience. In 2019, about 2.6% of undergraduate students and 1.5% of graduate students signed up for CWIE in Thailand. These numbers are far below the numbers of some other countries. Canada has 48.7% of undergraduate and 34% of graduate students participating in the work-integrated learning.

The new Higher Education Act B.E. 2562 introduced the higher education sandbox measure allowing the development of new and innovative forms of education such as customized curriculum and a program that engages industry in the curriculum design and delivery. Procedures and guidelines for universities to establish education sandboxes are being developed.

Thailand’s Student Loan Program - which currently has two types of loan i.e., the mortgage style loan and income contingent loan - is the main policy to reduce educational inequality. In 2021, the eligibility has been broadened to cover destitute students, students pursuing education in fields critical to the national development, students pursuing education in fields of shortage, and students with good academic performance.

Enabling Universities to Meet the Country’s Needs

Over the past few years, a number of initiatives have been introduced to enable Thai universities to meet increasing demands of the country in multiple dimensions.

- **Universities for Entrepreneurial Development** by enriching an innovation ecosystem in the university, fostering an entrepreneurial mindset in students and developing students’ entrepreneurial skills. Examples of programs that have been launched include Technology and Innovation-based Enterprise Development Fund (TED Fund), Startup Thailand League competition, and University Holding Company measure. TED Fund has supported 63 projects,

creating a THB 437.15 million socio-economic impact, generating a THB 46.01 million profit to enterprises, while reducing a THB 60.88 million operational costs.

- **Universities for Area-Based Development** with programs such as regional science parks, an establishment of Program Management Unit for Area-based Development (PMU-A), the University to Tambon (subdistrict) or U2T project and promoting the role of Rajabhat University Network as the driver of area-based development. Chief among high-impact projects implemented by PMU-A is the Targeted Poverty Eradication which was piloted in 20 poorest provinces during 2020-2021. The project, implemented in collaboration with 20 universities, has transformed 290,000 poor people into knowledge workers and smart farmers with higher income and better quality of life. The U2T project utilizing technology and innovation to drive community development has been implemented in 3,000 subdistricts. The project has added 53,263 new jobs to the communities and upskilled 8,685 workers. The U2T project is expected to bring THB 700 million/month economic impact to each community.
- **Universities for Frontier Research** in areas such as quantum technology, earth and space system, high energy physics and social sciences, humanities and arts (SHA). The 2020-2030 Quantum Technology Roadmap has been formulated by a consortium of 10 universities and 5 research and innovation agencies with a goal to have Thailand ranked among Asia's top 5 countries in quantum technology. Under genomic medicine, a project to set up a genomic medicine center at the Eastern Economic Corridor (EEC) by Burapha University has been approved, and a plan to establish Genomics Thailand Clinical Research Unit in 22 public hospitals and university hospitals across the country is underway.
- **University-Industry Linkage** as a key strategy to develop students, faculty members and researchers via Talent Mobility Program. From 2013-2020, Talent Mobility has facilitated a mobility of 1,107 university lecturers/researchers and 1,048 students and had 518 enterprises participating.
- **International Talent Attraction and Retention** with an establishment of Strategic Talent Center (STC) by the Board of Investment (BOI), the smart visa that offers convenience and privileges to foreign skilled workers, investors, executives and startups entrepreneurs, and the development of conducive environment and infrastructure at the Eastern Economic Corridor (EEC).
- **Global Partnership** via programs such as the Newton UK-Thailand Research and Innovation Partnership Fund and Thailand-CERN (the European Organization for Nuclear Research) collaboration in physics. Since its launch in 2014, the Newton UK-Thailand Research and Innovation Partnership Fund has grown steadily, with the budget of £ 2-4 million per year contributed by each side. The fund has supported 132 doctoral studies and research fellowships in the UK to 56 young Thai researchers. Training fellowships have been granted to 112 mid-career researchers and lab technicians. The Institutional Links and Impact Scheme has funded 45 projects which have led to an additional 64 projects and 166 activities and generated 105 joint publications, 51 products, 4 Ips and 11 databases and prototypes. Since 2010, The Thailand-CERN collaboration has supported 46 Thai graduate students and researchers to perform research work at CERN and 29 Thai students to participate in the CERN Summer Student

Program. Research results of Thailand-CERN collaboration are housed at the National e-Science Infrastructure to further support high energy physics studies in Thailand. Since 2011, the infrastructure has supported 246 projects and 251 users, resulting in 287 research publications.

HIGHER EDUCATION, SCIENCE, RESEARCH AND INNOVATION SYSTEM REFORM

In 2019, a new ministry – Ministry of Higher Education, Science, Research and Innovation (MHESI) - was established, combining higher education and science to create a unified force to drive an innovation-driven economy. The National Higher Education, Science, Research and Innovation Policy Council (Policy Council) – also formed in 2019 – represents the highest body to set policy and direction regarding higher education and science in Thailand. The launch of the new ministry set off a major reform of Thailand’s higher education, science, research and innovation system.

Establishment of Program Management Units

To increase the coverage of public funding in strategic research and innovation areas, three new research granting bodies were established in November 2019 as sandbox units under the auspices of NXPO with the goal to spin off as independent organization(s) after a certain period. These three units are (1) Program Management Unit for Area-based Development (PMU-A), (2) Program Management Unit for Human Resources & Institutional Development, Research and Innovation (PMU-B), and (3) Program Management Unit for National Competitiveness Enhancement (PMU-C).

The consolidation also resulted in five organizations coming under the direct purview of MHESI. These organizations are the Office of MHESI Permanent Secretary, the Office of MHESI Minister, the National Research Council of Thailand, the Department of Science Service and the Office of Atoms for Peace.

Higher Education, Science, Research and Innovation Strategy and Plan 2020-2027

The Higher Education, Science, Research and Innovation Strategy and Plan (2020-2027) was formulated taking into account the 20-year National Strategy, the domestic and international situations, the government reform and global challenges. The 2020-2027 Strategy and Plan consists of four platforms: (1) manpower and knowledge development; (2) research, development and innovation for grand challenges; (3) research, development and innovation for competitiveness; and (4) research and development for area-based development and inclusiveness. Each platform contains Objectives and Key Results (OKR) and programs serving as a blueprint for implementation.

Budget System Transformation

The budget system transformation was deemed an urgent matter necessary for driving the government policy. The Science, Research and Innovation Fund was established to enable block grant and multi-year budget allocation and management. Since its inception, the Policy Council has reviewed and submitted an annual budget for science, research and innovation fund for the government allocation. The budget of THB 24 billion and THB 19.92 billion was allocated for FY 2020 and FY 2021, respectively.

Monitoring and Evaluation System

For science, research and innovation, the monitoring and evaluation system is implemented in two aspects: (1) research and innovation capacity by assessing outputs, outcomes and impacts of research; and (2) performance of granting agencies by evaluating their abilities to execute implementation plans and enable the utilization of research and innovation, as well as process efficiency.

For higher education, the monitoring and evaluation system covers four aspects: (1) achievements of the Manpower Development Plan 2021-2037 and Higher Education Plan, (2) quality & development, (3) key policies result & progress, and (4) budget & output.

Data Integration

An integrative database system has been designed under the cooperative effort of NXPO, the Thailand Science Research and Innovation (TSRI), the Office of MHESI Permanent Secretary and the National Research Council of Thailand (NRCT). Thus far, the following has been achieved:

1. Data Architecture consists of four levels: Business Architecture, Application, Data & Database, and Technology.
2. Data Integration consists of the National Research and Innovation Information System (NRIIS), the Higher Education UNICON and the National Science and Technology Information System (NSTIS).

Regulatory Framework

Regulatory framework has been reviewed, and barriers have been removed to ensure that it supports the system reform and facilitates a complete innovation ecosystem to drive an innovation-based economy. Progress has been made with regard to easing the government procurement regulations and expanding the eligibility of government funding recipients to include the private and civil sectors.

FUTURE OUTLOOK OF HIGHER EDUCATION, SCIENCE, RESEARCH AND INNOVATION

To meet the target of the 20-year National Strategy, the higher education, science, research and innovation development will follow these directions:

- **Turning Poverty to Prosperity.** The focus is placed on unlocking the entrepreneurial potential of the locals to raise income and quality of life along with infrastructure and industrial development to establish regional economic

corridor. A “targeted poverty eradication” approach will be employed to solve poverty by launching projects to uplift the economic and social hardship in each community based on economic problems identified from the root cause analysis. Regional economic corridors and inclusive innovation will be developed to create innovation-based enterprises and jobs in all regions of Thailand.

- **Promoting Human Values, Social Changes & Sustainability.** This strategic direction focuses on ensuring human security, promoting human development, embracing diversity, advocating social justice, engaging people in local and national politics, understanding geopolitics and having awareness of environmental and technological issues affecting society. Strengthening capacity to enable human security and development; recognizing the powerful roles of arts and culture and applying them to create the economic and social value; engaging in sustainable management of environment and resources; and building resilience to disruption are among key answers to this strategic direction.
- **Implementing Bio-Circular-Green Economy (BCG).** In the BCG model, higher education, science, research and innovation are employed to turn Thailand’s comparative advantage in biological and cultural diversity into competitive advantage, thus enabling the country to thrive in the global market. The BCG model will be applied to promote four major industries– namely agriculture and food; medical and wellness; bioenergy, biomaterial and biochemical; and tourism and creative economy. Strong policy and actions will be developed to drive a circular economy transformation and build a dynamic ecosystem with key scientific infrastructures and regulatory framework that supports the growth of BCG businesses.
- **Transforming Industry & Building Foundation for the Future.** To invigorate the economy, policies and actions will be developed to bolster technological capacity of its industry by embracing Industry 4.0, increase the number of tech-based enterprises, strengthen frontier research to build groundwork for the future development and empower the society with social sciences, arts and humanities. Potential interventions include development of innovation driven enterprises (IDEs), promotion of next-generation manufacturing and service industry with advanced technologies such as digital technology, artificial intelligence and the future of mobility, as well as building big science and frontier research infrastructures in order to establish scientific excellence, enhance competitiveness, attract national and international talent and collaborations, draw S&T investment and enrich the innovation ecosystem.
- **Reinventing Higher Education & Human Capital.** The reinvention of higher education institutes will enable them to contribute to the economic and social development more effectively through fostering innovation and increasing higher skill levels of workforce. A quadruple helix model will be introduced to enable universities to value both excellence and relevance, build society’s resilience and cultivate entrepreneurial mindsets. More education programs will be offered to prepare the workforce with knowledge and skills fit for the social and economic development and support lifelong learning. Ecosystems will be developed to foster brainpower development, employing mechanisms to build up a quality

workforce as well as attracting foreign talent to fulfil the demand of current and future development.

- **Reforming Higher Education, Science, Research and Innovation System.** The system reform will bring about agility and accountability, supporting an overall performance improvement. Along with the system restructuring, organizational development will also be employed to improve efficiency and productivity of organizations in the system. The process will enable organizations to better respond and adapt to new business models which employ research and innovation to enhance competitiveness.